Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 8, Issue, 12, pp.42784-42789, December, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

DEGRADATION OF RESIDUES AND FOOD ACTIVITY IN SOILS WITH BIOLOGICAL ACTIVATION

[1*]Gerusa Pauli Kist Steffen, [1]Joseila Maldaner, [1]Rosana Matos de Morais, [1]Cléber Witt Saldanha, [2]Ricardo Bemfica Steffen, [3]Zaida Inês Antoniolli and [3]Rodrigo Josemar Seminotti Jacques

[1]State Foundation of Agricultural Research, Rio Grande do Sul, Brazil
[2]Renovagro - Renewable Agriculture, Brazil
[3]Department of Soils, Federal University of Santa Maria, Brazil

ARTICLE INFO

Article History:
Received 09th September, 2016
Received in revised form
19th October, 2016
Accepted 22nd November, 2016
Published online 30th December, 2016

Key words:
Soil Biology,
Bioactivation,
Food Consumption,
Soil Quality.

ABSTRACT

Soil biological activity is a key component for maintaining crop production sustainability. This study aimed to evaluate the effects of mineral fertilization (phosphorus and potassium) and soil and plant bioactivation (Penergetic technology) in agricultural crops by assessing food consumption of fauna and edaphic microorganisms. The tests were conducted on soybean (summer) and wheat (winter) crops subjected to different forms of fertilization and application of bioactivator. To assess food consumption in experimental plots, was used the bait-lamina methodology. The bait-laminas remained in the soil for 21 days. The percentages of empty, partially empty and full holes were evaluated in two soil layers: 0 to 8 and 9 to 16 cm deep, in addition to attributing scores to the pattern of food consumption. Principal component analyses were performed (PCA) using the feeding activity results, food consumption scores, crop yields and basal respiration. The combined use of bioactivator with phosphorus and potassium mineral fertilizer promoted a significant effect on feeding activity of fauna and micro-organisms present in the 0-8 cm soil layer in the soybean crop. There was no significant effect of soil fertilization and bioactivator on soil biological activity in the winter crop (wheat).

Citation: Steffen, G. P., Maldaner, J., Morais, R. M. de., Saldanha, C. W., Steffen, R. B., Antoniolli, Z. I., Jacques, R. J. S. 2016. "Degradation of residues and food activity in soils with biological activation", *International Journal of Current Research*, 8, (12), 42784-42789.

INTRODUCTION

Organisms and microorganisms living in the soil interfere directly and indirectly in biogeochemical cycles of elements and plant nutrition. Although the nutrient mineralization process is dependent on the action of microorganisms, soil fauna plays an important role in this process through regular microbial populations (Trogello *et al*., 2008; Socarrás and Izquierdo, 2014). Furthermore, the various groups which comprise the soil fauna play important systemic services, such as: initial fragmentation of detritus; stimulation, digestion and spread of microorganisms; and selective predation of fungi and bacteria; and these actions directly interfere in the decomposition of organic matter altering the availability of nutrients for plants (Cragg and Bardgett, 2001). The soil fauna influences nutrient cycling processes through two main routes: directly, by physical modification of litter and the soil environment, and indirectly, through interactions with the microbial community.

***Corresponding author: Gerusa Pauli Kist Steffen,**
State Foundation of Agricultural Research, Rio Grande do Sul, Brazil.

Its direct effects on biogeochemical cycling occur through fragmentation and incorporation of plant debris into the soil, promoting an increase in the availability of nutritional resources for microorganisms and mediating the transfer of solutes and particles deep into the soil profile (Decaëns *et al*., 2003; Trogello *et al*., 2008). They also affect the biogeochemical cycling through physical rearrangement of the soil particles, changing the pore size and distribution and, consequently, the infiltration and gas emission patterns (Beare *et al*., 1995). Changes imposed by land use, in particular by agriculture, impact the fauna and microorganisms, in varying degrees of intensity (Alvarez *et al*., 2001), either due to changes in soil properties, or by direct actions of these practices on the organisms. Measurements of soil biota feed consumption are indicators of decomposition rates (Reinecke *et al*., 2008) and functional integrity of ecosystems (Filzek *et al*., 2004). Originally developed by von Törne (1990) to assess in situ feeding activity of soil organisms, the bait-lamina test is a tool to detect changes in the food consumption pattern of soil fauna in environments subject to different products or management practices, whether harmful or beneficial. The energizing process used by Penergetic technology comes from the theories proposed by Michael Faraday in 1846, and James Clerk Maxwell in 1864, both physicists who worked on the issue of energizing material (Pauli, 1927; Dirac, 1928; Noack, 1985). In the 60s, it was observed that some bacterial genera showed the surprising behavior of persistently migrating toward the north geomagnetic pole even when the sample orientation on a slide was changed by rotating the microscope stage (Bellini, 1963). Since then, research has been performed in order to understand this mechanism. Bellini (2009), investigating electromagnetic motion, showed that proton and electron movement occurs differently and, that together with the force of gravity, this movement generates a frequency direction that guides the movement of certain microorganisms. Currently, there are many studies showing the effect of electromagnetic energy on microbial activity (Diego *et al*., 2003; Diego *et al*., 2012), as well as on orientation and feeding activity of soil organisms (Esquivel *et al*., 2004; Hsu *et al*., 2007; Wajnberg *et al*., 2010) and crops (Pieturszewski, 1993; Pothakamury *et al*., 1997; Hajnorouzia *et al*., 2001; Novitsky *et al*., 2001; Zapata *et al*., 2002; Souza-Torres *et al*., 2006; Pekarskas *et al*., 2011; Ladino *et al*., 2012; Padrino *et al*., 2013). This study aimed to evaluate the effects of mineral fertilization (phosphorus and potassium) and Penergetic technology on soil bioactivation in agricultural crops through the assessment of food consumption of edaphic fauna and microfauna.

MATERIALS AND METHODS

Tests were conducted on soybean and wheat crops exposed to different fertilization techniques and application of bioactivator (Penergetic technology) in the agricultural year 2014 in Julio de Castilhos, RS, Brazil. Four treatments were established: T1 = control without fertilization (Cont.); T2 = control + bioactivator (Cont. + P); T3 = phosphorus and potassium as recommended by CQFS-RS/SC (Rec.) and T4 = phosphorus and potassium as recommended by CQFS-RS/SC + bioactivator (Rec. + P). The bioactivator was applied at 250 g ha^{-1} of each of the products: Penergetic Pflanzen (sprinkling on the shoot) and Penergetic Kompost (applied to the soil). Based on phosphorus and potassium initial contents in the soil, 50 kg of P_2O_5 and K_2O 80 h^{-1} were added for T3 and T4. The slides used in the assay were prepared according to the German commercial supplier Terra Protecta (1999). Each bait-lamina consists of a 16-cm-long polyvinyl chloride (PVC) slide with 16 holes spaced 0.5 cm apart. The holes were filled with a substrate made of a homogeneous mixture of cellulose, wheat flour and activated carbon (70:27:3). Thirty bait-laminas for each experimental plot were inserted vertically in the soil with the aid of a metal blade to slit open the soil. The bait-laminas were arranged in between the crop rows in two groups of 15 slides about 5 meters apart. The test took place over 21 days, after which all slides were collected.

Collected slides were individually stored in paper bags for laboratory processing. The results were expressed as percentage of empty, partially empty and full holes in the two layers of soil. For the 0 to 8 cm layer the first eight holes were considered and for the 9 to 16 cm layer the 9th to 16th holes were considered. Consumption pattern scores were given for each of the 16 holes in accordance with the observed fill pattern: empty hole (score 3), partially empty (score 2) and full hole (score 1). Based on the consumption pattern scores, we calculated an average rate of consumption for each treatment. Thus, the higher the average value assigned to the slide due to higher consumption of substrate, the greater the feeding activity of organisms and microorganisms in the experimental plot. We performed principal component analysis (PCA) from the feeding activity results, feeding activity scores, crop yields and basal respiration. The basal respiration data served as supporting data to demonstrate microbial activity in the studied soil. For basal respiration analysis 100g of soil were incubated in 800mL glass jars with airtight lids at 26 °C at a humidity near to field capacity for 20 days. Soil samples without soil were incubated in triplicate and the same procedure was carried out for control jars without soil. In each jar a 50 ml plastic cup containing 20 mL of 0.5 M NaOH was added in order to capture the CO_2 produced by microbial soil respiration. The CO_2 was quantified by titration with 0.5M HCl following previous addition of 1 ml 30% $BaCl_2$ and phenolphthalein as indicator. The relationship between feeding activity and fertilization treatments was assessed by the order generated by the principal component analysis (PCA), using the CANOCO software, Version 4.0 (Ter Braak and Smilauer, 1998). The results were submitted to analysis of variance between treatments through Sisvar software (Ferreira, 2011). The means of each treatment were compared by Tukey range multiple test at 5% probability ($p<0.05$).

RESULTS

Higher average percentage of completely filled holes was observed on the blades deposited in the soil portion of the witness in relation to other treatments, for both analyzed depths in the cultivation of soybean (Fig 1 and 2). The substrate residence not accessed by the fauna and the microorganisms in the holes of the blades indicates less biological activity in the soil, enabling comparisons between the consumption intensity pattern of substrate at each of the treatments in the field. Regarding the percentage of completely empty holes in soybean cultivation in the layer 0-8 cm, there were also significant differences between treatments, while the highest average percentage (32.1%) was observed in the plot that received phosphate fertilizer and potassium associated with the application of Penergetic technology, differentiating the control treatment (Fig 1). These results indicate that the isolated or combined addition of mineral fertilizers and Penergetic can be positively influenced the community activity in the soil, resulting in increased feeding activity in the layer 0 and 16 cm in summer crop (Fig 1 and 2).

The Penergetic technology is based on the vehicle energizing process (bentonite or calcium carbonate), which can be obtained through electromagnetic waves at a reduced spectrum. Such energy load acts in the induction of biological activity observed naturally in soil systems/plant, plant/atmosphere and soil/microorganisms, acting as a bioactivator of biological activity in the soil. In all treatments evaluated in soybean cultivation in the most superficial layer of soil were observed average percentage of partially void holes exceeding 50%, highlighting the treatment relative to the isolated application of Penergetic technology, which showed 70.4% holes partially consumed by the biological community of the soil, differing significantly from the control (Fig 1). Comparing the organisms standard food consumption of the layer 0 to 8 cm in wheat crop, it was observed that there was no differentiation of the treatments (Fig 1). Similar results were observed in the layer 9 to 16 cm (Fig 2). When grading the standard of substrate consumption within the bait-lamina holes, the effect of mineral fertilizer combined or not with Penergetic technology on bioactivation of biota and soil microbiota is even more evident.

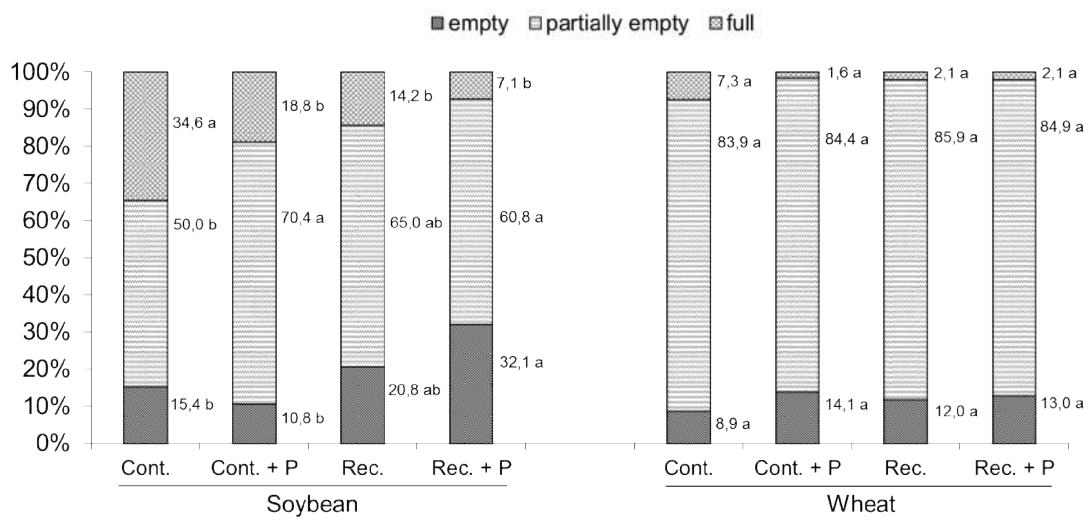

Fig 1. Percentage of empty, partially empty and full holes at 0-8 cm soil layer, indicating the feeding activity of organisms in soybean and wheat crops submitted to different treatments. Replication number: 30. Means with the same letter for each level of consumption indicate no significant differences among treatments (p≤0.05) according to Tukey's multiple range test

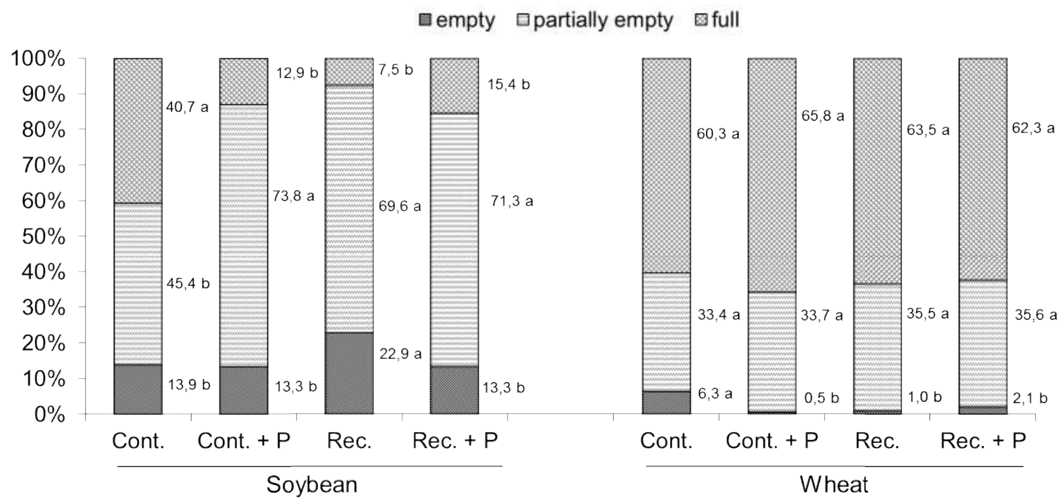

Fig 2. Percentage of empty, partially empty and full holes at 9-16 cm soil layer, indicating the feeding activity of organisms in soybean and wheat crops submitted to different treatments. Replication number: 30. Means with the same letter for each level of consumption indicate no significant differences among treatments (p≤0.05) according to Tukey's multiple range test

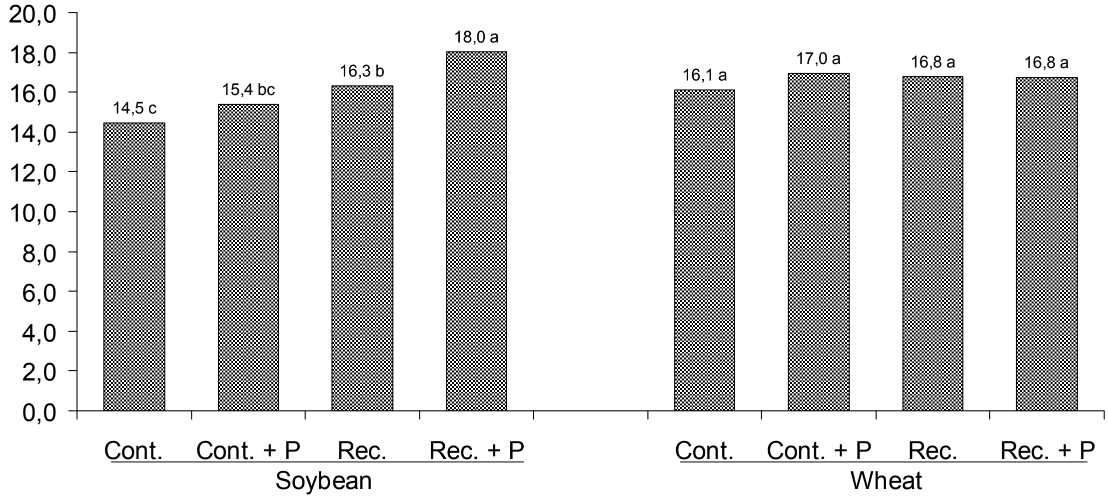

Fig 3. Average rate of soil organism food consumption at 0-8 cm layer, calculated by assigning scores for substrate consumption in soybean and wheat crops. Scores: 1 (full hole) 2 (partially empty) and 3 (completely empty). Statistical test: Tukey at 5% probability (p≤0.05). Replication number: 30

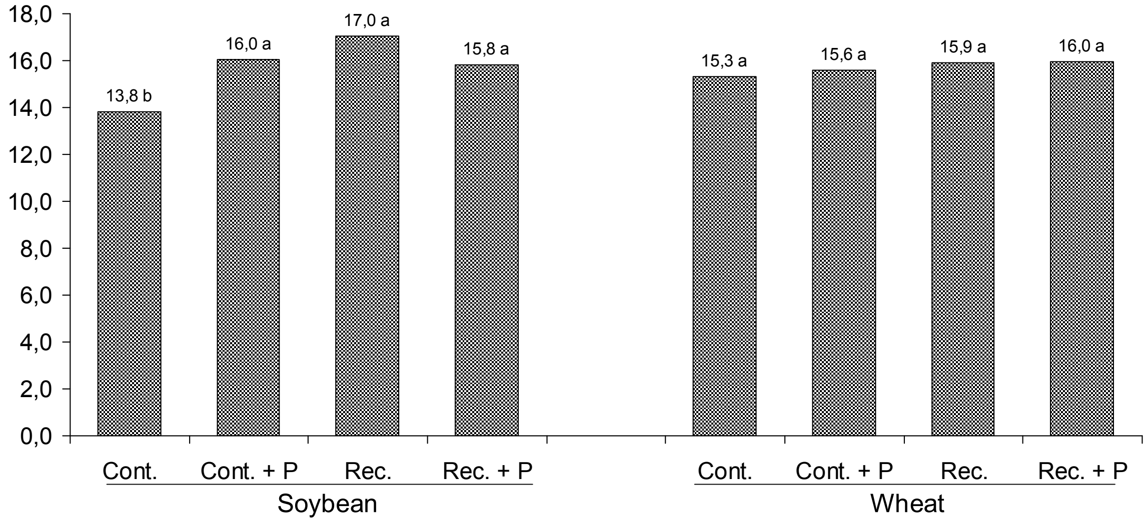

Fig 4. Average rate of soil organism food consumption at 9-16 cm layer, calculated by assigning scores for substrate consumption in soybean and wheat crops. Scores: 1 (full hole) 2 (partially empty) and 3 (completely empty). Statistical test: Tukey at 5% probability (p≤0.05). Replication number: 30

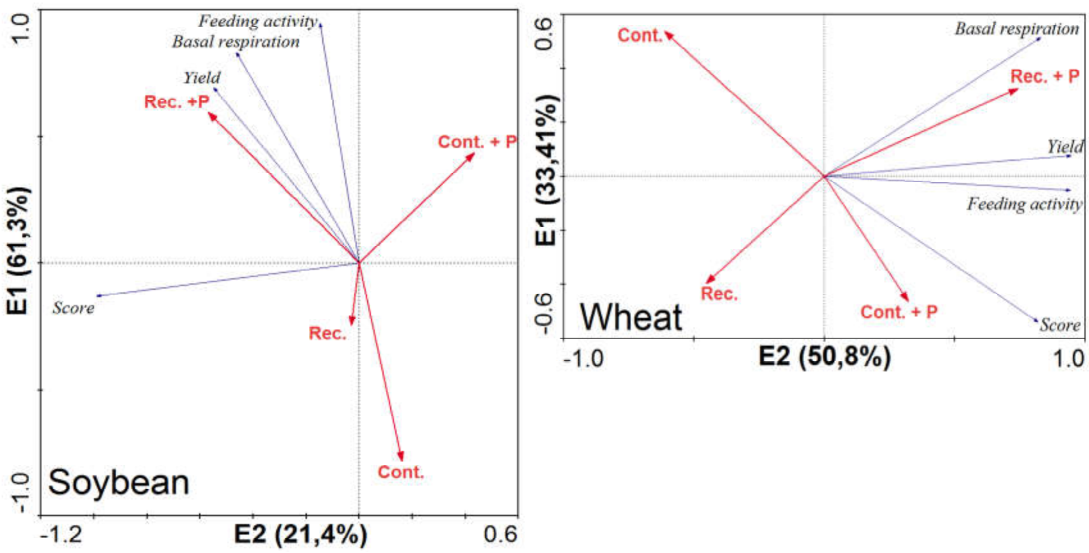

Fig 5. Graphic representation of the principal component analysis (PCA) relating the dimensions 1 and 2 concerning the soil organisms feeding activity and productivity of soybean and wheat crops in different managements of mineral fertilizers (phosphorus and potassium) and Penergetic technology

For both soil layers evaluated in soybean crop, blades deposited in control plots (without Penergetic and mineral fertilizers application) had significantly lower values indicating lower biological activity than the other treatments (Fig 3 and 4). In the soybean crop, comparing only the fauna and microfauna feeding activity in the most superficial layer of soil (0-8 cm), where there is greater diversity of species and abundance of organisms, it was observed that the combination of soil fertility correction and applying Penergetic technology resulted in significant increase of the biological activity of the soil by increasing food intake. In the layer 9-16 cm, although it was observed effect isolated or combined application of Penergetic and mineral fertilizers in fauna and microfauna food consumption in relation to the control, there was no significant difference between the three treatments (Fig 4). The bait-laminas arranged in the soil on wheat crop, again no significant differences were observed between treatments in both evaluated layers, when the index was calculated by assigning notes as the standard substrate consumption (Fig 3 and 4).

It was observed positive effect of the correction of phosphorus and potassium in the soil, as well as isolated or combined application of Penergetic technology on the fauna and microfauna feeding activity on the soybean crop soil. At the top soil (0-8 cm), the correction of the levels of these nutrients together with the use of Penergetic seems to have bioactivated and/or stimulated the biological activity of the soil, being observed higher percentage of totally void holes (32.1%) and lower percentage of holes completely filled (7.1%) in this treatment (Fig 3). The multivariate model used to evaluate the soil organisms feeding activity in different managements of fertilization, showed variability among crops (soybean and wheat) and from the use or not of Penergetic technology (Fig 5). For soybean crop, the axis 1 (E1) explained 61.3% of the observed response on the feeding activity, basal respiration and crop yield, demonstrating that these parameters were directly related to the use of Penergetic technology. For wheat crop, the axis 2 (E2) explained 50.8% of the response pattern. For this period, the crop yield and the feeding activity showed similar responses with and without mineral fertilizers, since associated with Penergetic technology.

DISCUSSION

The feeding activity of the soil community directly affects the dynamics of nutrient cycling and thus plant nutrition. From an agricultural point of view, the stimulus of biological activity at the root growth zone is desirable, since the interaction between microorganisms and soil fauna interfere with decomposition, organic matter mineralization and nutrients cycling, contributing to better use and available of elements for plants (Cragg and Bardgett, 2001). The Penergetic technology has been used in agriculture to bioactivate microorganisms and soil fauna in soil systems. Its action is due to the addition of charged particles, which are introduced via pulverization to the soil and plants. Upon contact with the soil, this energy acts in a beneficial way, affecting biota and soil microbiota activity and plant nutrient availability. The use of Penergetic technology significantly affected the stimulation of microorganisms and fauna in the soil of the soybean crop (Fig 1).

However, the effect was even more evident when the technology was utilized in conjunction with the mineral fertilizer to correct phosphorus and potassium levels (Fig 1 and 3). These results may be related to an activation effect provided by the energy. According to Silva Filho *et al*. (2002), solubilizing microorganisms are found between 10^4 and 10^7 g^{-1} soil, depending on the location and evaluation method, and to the order of 10^6 g^{-1} for rhizosphere soil of various legumes. The interactions between microorganisms and between the microorganisms and the environment are well-known. However, the vast majority of available information is related to the use of biochemical signals across microorganisms. Recent studies have shown that in addition to biochemical signals, fungi and bacteria can "communicate" with the environment through electromagnetic signals (Cifra *et al*., 2011; Dotta *et al*., 2011; Dotta and Rouleau, 2014). The absence of a significant effect of Penergetic technology and phosphate and potassium fertilizer on wheat crops (Fig 1, 2, 3 and 4) may be related to climatic conditions of the region where the study was conducted, characterized by occurrence of temperatures below 10 °C in winter (Lima *et al*., 2013). Thus, it is possible that the low temperatures may have inhibited biological activity in the soil. Microorganism activity and nutrient mineralization rates depend on the temperature, humidity, aeration and quantity and nature of organic material present in the soil (Mary *et al*., 1996). Camargo *et al*. (1997) evaluated nitrogen mineralization rates in different soils of Rio Grande do Sul (Brazil) and attributed the relatively low potential for mineralization of a particular soil to conditions of low average annual temperature, low acidity and high aluminum saturation. According to those authors, these conditions establish an environment that is little biologically active, resulting in low nutrient mineralization rates. Lourente *et al*. (2011), investigating microbiological soil properties in both winter and summer, also found reduced soil microbial activity in the colder season. The carbon content of the microbial biomass was on average 71% higher in the summer, characterized by high temperatures and increased precipitation. The authors attributed the lower microbial activity observed in the coldest season (winter) to low temperatures and lower rainfall intensity, since the increase in air temperature and soil moisture in summer, provided favorable conditions for soil microorganisms (Espíndola *et al*., 2001). Great efforts have made recently to find a new model of agriculture that is able to produce quality food with reduced use of chemical inputs in order to reduce production costs and preserve the environment. Questions regarding the need for and the excessive use of mineral fertilizers in agricultural crops have been raised for decades, leading to an active search for alternatives to ensure the sustainability of agriculture. The cost of mineral fertilizers, especially phosphate, has been increasing progressively and phosphate reserves are being consumed at an accelerated pace, hampering this practice in the future. Therefore, the proposal of new technologies is necessary to improve the quality and productivity of agricultural systems and ensure the survival of organisms and microorganisms present in the system. Biostimulation of lifeforms that exist in the soil contributes to the sustainability of agriculture, in addition to acting directly on the cycling of organic matter and contributing to reduce the requirement for external input of nutrients in crops.

Conclusion

The combined use of Penergetic technology with phosphorus and potassium mineral fertilization promoted a significant effect on the feeding activity of fauna and microorganisms present in the 0-8 cm soil layer in soybean. The feeding activity of fauna and microorganisms in the 9-16 cm soil layer was intensified with the use of Penergetic technology, alone or it combination with phosphate and potassium fertilization, in soybean. Soil fertility correction practices and the use of Penergetic technology did not significantly increase soil biological activity in the winter crop.

Acknowledgement

Authors are thankful to the State Foundation of Agricultural Research of Rio Grande do Sul, to the Federal University of Santa Maria and to the Research Foundation on the State of Rio Grande do Sul (FAPERGS) for financial support.

REFERENCES

Alvarez, T., Frampton, G.K., Goulson, D. 2001. Epigeic Collembola in wheat hunter organic, integrated and conventional farm management regimes. Agric Ecosyst Environ, 83: 95-110.

Beare, M.H., Coleman, D.C., Crossley, Jr. D.A., Hendrix, P.F., Odum, E.P. 1995. A hierarchical approach to evaluating the significance of soil biodiversity to biogeochemical cycling. Plant Soil, 170: 5-22.

Bellini, S. 1963. Ulteriori studi sui "batteri magnetosensibili". Institute of Microbiology, University of Pavia, Italy.

Bellini, S. 2009. Further studies on "magnetosensitive bacteria". Chin. J. Oceanol. Limnol, 27: 6-12.

Camargo, F.A.O., Gianello, C., Vidor, C. 1997. Potencial de mineralização do nitrogênio em solos do Rio Grande do Sul. Rev. Bras. Cienc. Solo, 21: 575-579.

Costa, M.B.B. da. 2002. Sustentabilidade e manejo dos recursos naturais. *In*: Anais do Seminário sobre Gestão Sustentável dos Solos Agrícolas, Curitiba, Paraná, 1-10.

Cragg, R.G., Bardgett, R. 2001. How changes in soil faunal diversity and composition within a trophic group influence decomposition processes. Soil Biol. Biochem, 33: 2073-2081.

Cifra, M., Fields, J.Z., Farhadi, A. 2011. Electromagnetic cellular interactions. Prog. Biophys. ***Mol. Biol,*** 105: 223-246.

Comissão de Química e Fertilidade do Solo RS/SC (CQFS RS/SC). 2004. Manual de Adubação e de Calagem para os Estados do Rio Grande do Sul e de Santa Catarina. SBCS. Comissão de Química e Fertilidade do Solo, Porto Alegre.

Decaëns, T., Lavelle, P., Jiménez, J.J., Escobar, G., Rippstein, G., Schneidmadl, J., Sanz Scovino, J.I., Hoyos, P., Thomas, R.J. 2003. Impacto del uso de la tierra en la macrofauna del suelo de los Llanos Orientales de Colômbia. In: Jiménez JJ, Thomas RJ (eds) El arado natural: las comunidades de macroinvertebrados del suelo en las savanas neotropicales de Colombia. Publicación CIAT (n. 336), Cali: 21-45.

Diego, S.M.M., Morla, A.G., Sofia, M.C., Pulles, D.C. 2003. Growth of *Trichoderma reesei* on static and dynamic solid substrate fermentation under electromagnetic fields. In: Roussos S, Soccol CR, Pandey A, Augur C (eds) New Horizon on Biotechnology. Kluwer Academic Publisher: 57-62.

Diego, S.M.M, Manrique, C.M., Ricardo, F.S., Furigo, Jr. A. 2012. Análisis de factibilidad de la aplicación del campo electromagnético al proceso de producción de *Trichoderma reseei*. Invest Sab, 1: 61-64.

Dirac, P.A.M. 1928. The Quantum Theory of the Electron. Proceedings of the Royal Society of London, 117: 610–624.

Dotta, B.T., Buckner, C.A., Cameron, D., Lafrenie, R.M., Persinger, M.A. 2011. Biophoton emissions from cell cultures: biochemical evidence for the plasma membrane as the primary source. ***Gen. Physiol.*** Biophys, 30: 301-309.

Dotta, B.T., Rouleau, N.Y. 2014. Electromagnetic Fields as Structure-Function Zeitgebers in Biological Systems: Environmental Orchestrations of Morphogenesis and Consciousness. Front Integr Neurosc, 8: 84.

Espíndola, J.A.A., Almeida, D.L., Guerra, J.G.M., Silva, E.M.R. 2001. Flutuação sazonal da biomassa microbiana e teores de nitrato e amônio de solo coberto com *Paspalum notatum* em um agroecossistema. Floresta Ambient, 8: 104-113.

Esquivel, D.M.S., Wajnberg, E., Cernicchiaro, G.R, Alves, O.C. 2004. Comparative magnetic measurements of migratory ant and its only termite prey. J Magn Magn Mater, 278: 117-121.

Ferreira, D.F. 2011. Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia, vol.35, no.6: 1039-1042.

Filzek, P.D.B., Spurgeon, D.J., Broll, G., Svendsen, C., Hankard, P.K., Parekh, N., Stubberud, H.E., Weeks, J.M. 2004. Metal Effects on soil invertebrate feeding: measurements using the bait-lamina method. Ecotoxicology, 13: 807-816.

Fixen, P.E. 2009. Reservas mundiais de nutrientes dos fertilizantes. Informações Agronômicas, n. 126. Piracicaba: International Plant Nutrition Institute, IPNI: 8-14.

Hajnorouzia, A., Vaezzadeha, M., Ghanatib, F., Jamnezhada, H., Nahidianb, B. 2001. Growth promotion and a decrease of oxidative stress in maize seedlings by a combination of geomagnetic and weak electromagnetic fields. J Plant Physiol, 168: 1123-1128.

Hsu, C.Y., Ko, F.Y., Li, C.W., Fann, K., Lue, J.T. 2007. Magnetoreception System in Honeybees (*Apis mellifera*). PLoS ONE 2(4): 395.

Ladino, E.A.H., Osorio, J.L.T., Lopez, L.B. 2012. Estudio del Efecto de la estimulación magnética de semillas de *Leucaena leucocephala* (Lam.) de Wit. Tecno Lógicas, 29: 33-47.

Lima, O., Melloni, R., Melloni, E.G.P. 2013. Antropização da zona de amortecimento da reserva biológica serra dos Toledos (Itajubá-MG) e seu efeito na qualidade do solo. Cerne, 19: 373-381.

Lourente, E.R.P., Mercante, F.M., Alovisi, A.M.T., Gomes, C.F., Gasparini, A.S., Nunes, C.M. 2011. Atributos microbiológicos, químicos e físicos de solo sob diferentes sistemas de manejo e condições de Cerrado. Pesq. Agropec. Trop, 41: 20-28.

Mary, B., Recous, S., Darwis, D., Robin, D. 1996. Interaction between decomposition of plant residues and nitrogen and nitrogen cycling in soil. Plant Soil, 181: 71-82.

Noack, C. 1985. Bemerkungen zur Quantentheorie des Bahndrehimpulses. Phys. Bl., 41: 283–285.

Novitsky, Y.I., Novitskaya, G.V., Kocheshkoiva, T.K., Nechiporenko, G.A., Dobrovolskii, M.V. 2001. Growth of green onions in a weak permanent magnetic field. Russ J Plant Physiol, 48: 709-715.

Padrino, M.V.C., Ramírez, E.M., García, M.F. 2013. Tratamiento magnético como técnica estimulante de la germinación de semillas de soja. Ingeniería de Recursos Naturales y del Ambiente, 12: 119-127.

Pauli, Jr. V.W. 1927. Zur Quantenmechanik des magnetischen Elektrons. Zeitschrift für Physik, 43: 601-623.

Pekarskas, J., Vilkenyte, L., Silekiene, D., Cesoniene, L., Makarenkos, N. 2011. Effect of organic nitrogen fertilizers provita and fermentator penergetic k winter wheat and on soil quality. Environmental Engineering**,** Lithuania.

Pieturszewski, S. 1993. Effect of magnetic seed treatment on yield of wheat. Seed Sci. Technol, 21: 621-626.

Pothakamury, U.R., Palou, E., Swanson, B.G. 1997. Oscillating magnetic fields for food processing. In: Barbosa-Cánovas GV, Pothakamury U, Palou E, Swanson BG. (eds) Nonthermal Preservation of Foods. New York: Marcel Dekker, Inc.: 113-138.

Reinecke, A.J., Albertus, R.M.C., Reinecke, A.S., Larink, O. 2008. The effects of organic and conventional management practices on feeding activity of soil organisms in vineyards. Afr. Zool. 43: 66-74.

Silva Filho, G.N., Narloch, C., Scharf, R. 2002. Solubilização de fosfatos naturais por microrganismos isolados de cultivos de *Pinus* e *Eucalyptus* de Santa Catarina. Pesq. Agropec. Bras, 37: 847-854.

Socarrás, A., Izquierdo, I. 2014. Evaluación de sistemas agroecológicos mediante indicadores biológicos de la calidad del suelo: mesofauna edáfica. Pastos y Forrajes, 37: 47-54.

Souza-Torres, A.D., Garcia, D., Sueiro, L., Gilart, F,. Porras, E., Licea, L. 2006. Pre-sowing magnetic treatments of tomato seeds increase the growth and yield of plants, Bioelectromagnetics, 7: 247-257.

Ter Braak, C.J.F., Smilauer, P. 1998. CANOCO reference manual and user's guide to Canoco for Windows: Software for canonical community ordination (version 4). New York: Microcomputer Power.

Trogello, E., Trogello, A.G., Silveira, E.R. 2008. Avaliação da Fauna do Solo em Diferentes Sistemas de Cultivo, Milho Orgânico e Milho em Plantio Direto. Rev Bras Biocienc, 6: 25-26.

Wajnberg, E., Acosta-Avalos, D., Alves, O.C., Oliveira, J.F., Srygley, R., Esquivel, D.M.S. 2010. Magnetoreception in eusocial insects: an update. J R Soc Interface, 7: 207-225.

Zapata, J., Moreno, G., Márquez, E. 2002. Efectos de los campos magnéticos sobre el crecimiento de *Saccharomyces cerevisiae*. Interciência, 27: 544-550.

****